Saint Elmo's Fire Corona by Using HVDC, HVAC and Tesla Coil

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Abstract

In this paper, corona inception voltages of the Saint Elmo's fire corona in non-uniform field were studied by high voltage DC (HVDC), high voltage AC (HVAC) and Tesla coil for generating Saint Elmo's fire corona to strike the classical ship model at high voltage research laboratory in Khon Kaen university, Thailand. In the experiment, the scale of classical ship is 1:500. The gap spacing of artificial cloud and electrode ship mast blade is varied in the range of 50-300 mm. The artificial cloud with high electric field is generated by means of HVDC, HVAC and Tesla coil generator. The results show that there is a good agreement between experimental and calculation. For long air terminal ship mast about 30 cm, the strike occurs in the ship of 110, 127 and 55 kV by HVDC, HVAC and Tesla coil, respectively. In the case of short to high gap of 0-300 mm, the Saint Elmo's fire phenomenon can only appear on the Tesla coil generator.

Keywords

Glow; Brush Discharge; Corposant, Corona; Partial Discharge; Lightning Strike; St. Elmo's Fire

Introduction

St. Elmo's fire is an luminescent corona and often audible discharge caused by the ionization of the air during a strong electric field around 3 MV/m. St. Elmo's fire is named after Erasmus of Formiae or St. Elmo. (Elmo's fire, corposant) which can also appear on the tips of cattle horns during a thunderstorm. The first Elmo's fire phenomenon was known for Mediterranean sailors who regarded it as a visitation of their patron saint, Elmo (Erasmus).

Corona inception: Corona inception voltage is the lowest voltage point starting to first discharge at which continuous corona of specified pulse amplitude occurs during the applied voltage. This corona inception voltage can be detected by using radio wave range.

Corona discharge: Partial breakdown of the air occurs due to a corona discharge on high voltage conductors at points with the highest electrical stress, sometimes seen as a bluish glow around high voltage wires and heard as a sizzling sound along high voltage power lines Corona also generates radio frequency noise that can also be heard as 'static' or buzzing on radio receivers. If this phenomenon happen to the ship we called St. Elmo's fire, or corposant. St. Elmo's fire is intermediate in nature.

This corona glow discharge event can be demonstrated in Fig. 1. By the assumption, it does not connect a high voltage to cause a discharge, only a high field strength and the ionization is limited to a small region around the electrode.

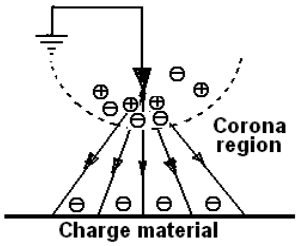


FIG. 1 GLOW DISCHARGE BY ASSUMING THAT IT DOES NOT TAKE A HIGH VOLTAGE TO CAUSE A DISCHARGE, ONLY A HIGH FIELD STRENGTH.

Spark discharge: The spark discharge, in Fig. 2, may take place between two well-rounded conductors at different potentials, one of which is often grounded .The spark discharge is a very fast process starting at a point where the breakdown field strength is exceeded.

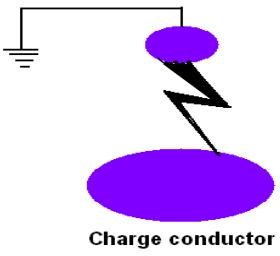


FIG. 2 THE SPARK DISCHARGE PHENOMENON.

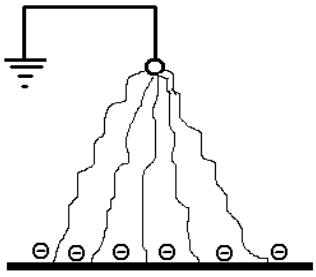


FIG. 3 BRUSH DISCHARGE PHENOMENON.

Brush discharge: This brush discharge, as shown in Fig. 3, happens between the corona glow discharges and the spark is the brush discharge, which may take place between a charged material and a normally grounded electrode with a small radius of curvature. If a brush discharge happens over longer periods, it may be appeared as lines irregular luminescent paths. Example of discharges from insulators is brush discharges as shown in Fig. 4.

FIG. 4 BRUSH DISCHARGE ALONG PIN TYPE INSULATOR AT KKU HIGH VOLTAGE ENGINEERING LABORATORY [4].

St. Elmo's fire: Appear from the tips, cattle horns of a ship after the discharge from the anvil cloud during a thunderstorm.

There are Five Types of Cloud Discharge, as Shown in Fig. 5.

a: Intra-cloud discharges. The most famous type of lightning is the intra-cloud discharge, in which the flash occurs entirely within the cloud.

b: Cloud to ground discharges. This lightning strike is the most important of lightning needed to study.

This study is the most pertinent to human life, as its effects are the most damaging. In cloud to ground lightning strike, the negative charge can induce a positive charge on the earth below. So the clouds and the earth act as a giant parallel plate capacitor.

c: Cloud to cloud discharges. The charge of lightning strike is strike from the center of negative charge to the center of positive charge. Sometimes, the charge of lightning strike is strike from the high intensity of negative charge to the high intensity of positive charge.

d: Cloud to air discharges. The charge of lightning strike is strike from the negative charge to the air.

e: Cloud to ship ground (water) discharges. This lightning strike is the most important of lightning needed to study. This study is required to protection the human life and ship from being damaged.

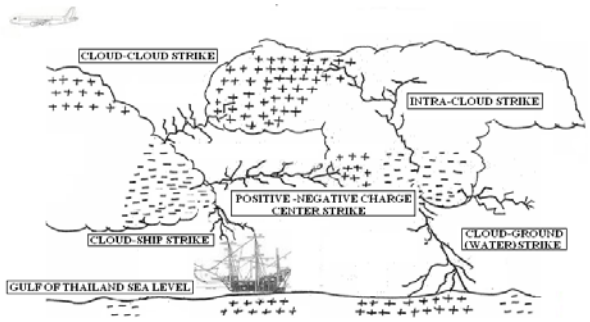


FIG. 5 TYPE OF CLOUD DISCHARGE PHENOMENON DURING STRIKE TO THE SHIP [5, 6, 7].

Experiment Set Up

HVDC TEST

1. The circuit is connected as shown in Fig. 6.

2. Start the test by varing the space between cloud and ship high pole mast point of 5.0 – 30.0 cm.

3. Switch on the circuit and raise the input voltage until output voltage creates the inception voltage between the cloud and mast spac.

4. Record the voltage waveform and magnitude data in Table 1.

5. From the inception voltage point, continuously raise the input voltage until output voltage creates the corona brush discharge voltage.

6. If in this point, bush discharge can be created.

7. Record voltage wave form and magnitude data in Table 1.

8. If this point cannot create, any brush discharge or can created bush discharge.

9. From this point, continuously raise the input voltage until output voltage creates the breakdown point. During the test, the magnitude of wave form is recorded in Table 1.

10. Switch of the circuit and ground.

11. Vary the space between cloud and ship high pole mast point to 10, 15, 20, 25 and 30 cm.

12. Repeat 3-10.

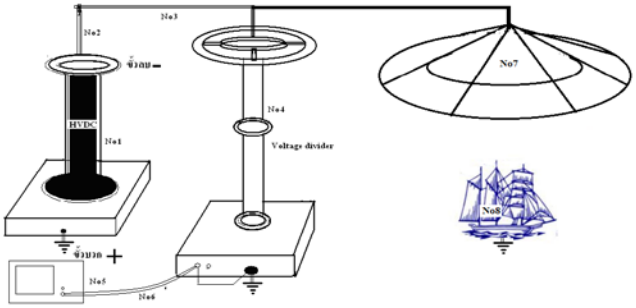


FIG. 6 HVDC EQUIPMENT SET UP TO TEST ST. ELMO'S FIRE [1, 3, 8].

HVAC TEST

HVAC test is the same as HVDC by using the circuit diagram, as shown in Fig. 7.

Apparatus Detail

No. 1.1 HVDC generator (Fig. 6)

No. 1.2 HVAC generator (Fig. 7)

No. 1.3 Tesla coil generator (Fig. 8)

No. 2 Aluminum hollow striate bus-bar diameter of 25.0 mm

No. 3 Aluminum hollow connector bus-bar diame-ter of 25.0 mm

No. 4.1 R-C-R voltage divider ratio of 1:609 for HVDC generator.

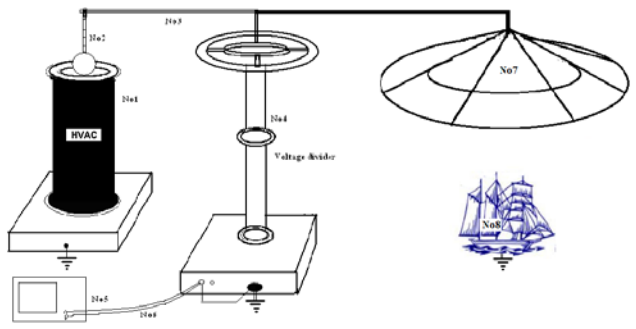


FIG. 7 HVAC EQUIPMENT SET UP TO TEST ST. ELMO'S FIRE [3, 4, 8].

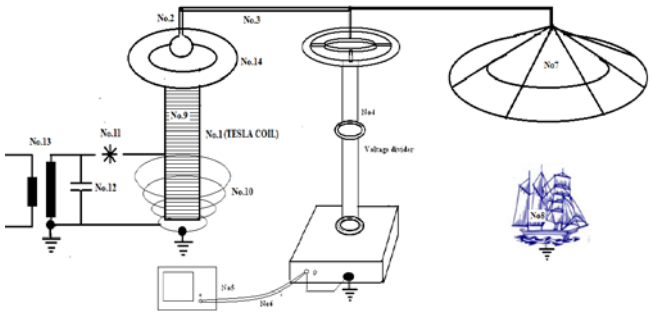


FIG. 8 TESLA COIL EQUIPMENT SET UP TO TEST ST. ELMO'S FIRE [1, 5, 8].

No. 4.2 Resistive voltage divider ratio of 1:58,000 for HVAC generator.

No. 4.3 R-C voltage divider ratio of 1:4,700 for Tesla coil generator.

No. 5 Oscilloscope.

No. 6 Coaxial RG6U Oscilloscope signal.

No. 7 Anvil artificial cloud.

No. 8 Classic ship model.

No. 9 Secondary Tesla coil winding.

No. 10 Primary Tesla coil winding.

No. 11 Quenching gap.

No. 12 Primary charging capacitor.

No. 13 Power supply transformer 220V/10-22kV.

No. 14 Toriodal capacitor.

Results and Discussions

TABLE 1 HVDC, HVAC AND TESLA COIL INCEPT VOLTAGE AND SPARK OVER VOLTAGE RESULTS.

Description of object	Gap (mm)	Corona incept voltage kV(Peak)			Spark over Voltage kV(Peak)			Field utilization factor		
		DC-	AC	Tesla	DC-	AC	Tesla	DC-	AC	Tesla
A)Classical ship	50	19.5	24.4	10.01	22.8	31	12.2	0.92	0.89	0.90
	100	25.9	43.8	11.69	40.6	68.4	18.3	0.81	0.82	0.80
cloud plate shaped / mast pole gap	150	32.8	57.4	19.94	57.4	74.8	29.8	0.78	0.88	0.82
	200	39.1	67.2	25.43	71.1	99	41.4	0.77	0.83	0.81
	250	45.7	73	23.93	94.4	113.7	42.5	0.74	0.82	0.79
	300	64.4	82.7	33.85	110	127.8	55	0.79	0.82	0.80
Temperature (degrees C):28					Barometric pressure (mmHg):745					

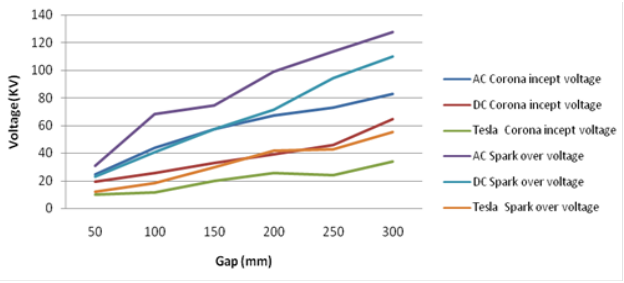


FIG. 9 THE INCEPTION VOLTAGE, SPARK OVER VOLTAGE VERSUS SPACING GAP.

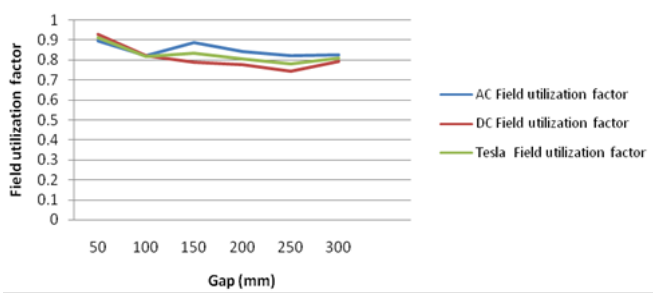


FIG. 10 FIELD UTILIZATION FACTOR VERSUS SPACING GAP.

FIG. 11 TYPICAL CORONA SPARK OVER VOLTAGE PHENOMENON LIGHTING LINES STRIKE BY USING HIGH VOLTAGE DC GENERATOR.

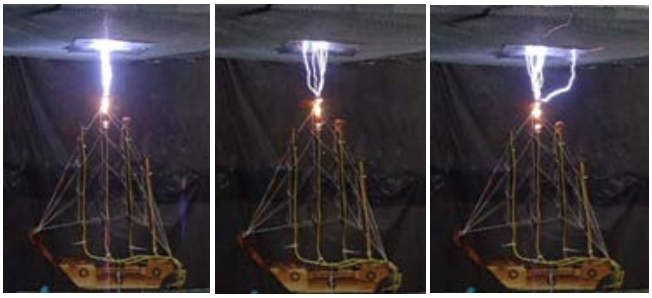
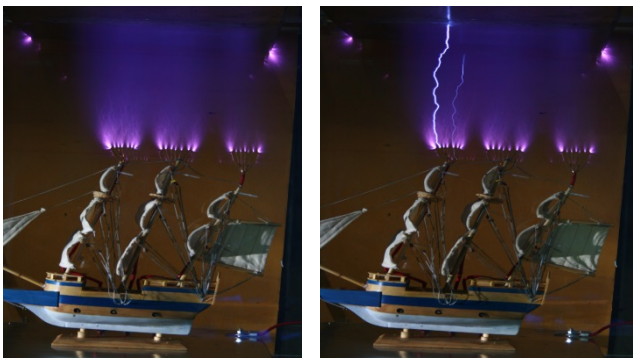


FIG. 12 LIGHTING BIG BEAM, STREAMERS LINES AND DEVIATE LINES STRIKE BY USING HIGH VOLTAGE AC GENERATOR.

FIG. 13 TYPICAL CORONA ST. ELMO'S FIRE, LIGHTNING AND STREAMERS LINES STRIKE PHENOMENON BY USING HIGH VOLTAGE TESLA COIL GENERATOR.



(A) (B)

FIG. 14 ST. ELMO'S FIRE ON A SHIP AT KKU HIGH VOLTAGE ENGINEERING LABORATORY: (A) GLOW AND BRUSH DISCHARGE AND (B) BRUSH AND SPARK DISCHARGE AT AIR PRESSURE OF 200 TORR.

St. Elmo's fire appearing as eerie blue "flames" can glow at the tips of ship's masts while travelling to the sea due to ions at ship's masts imbalanced because they have lost or gained electrons. The imbalance rips apart from molecules in the air and sometimes a soft hissing sound can be heard. This action releases electromagnetic energy, and St. Elmo's fire phenomenon glows for several minutes before dying out. The sailors regarded St. Elmo's fire as a good omen since it meant a thunderstorm which was winding down. St. Elmo's fire usually forms at the tips of tall objects because the reduced surface area requires less voltage for the oppositely charged particles to attract each other. From experiment in high voltage laboratory, the St. Elmo's fire corona phenomenon can appear after inception voltage until spark over voltage only using the Tesla generator. From Table 1 and Fig. 9-10, when Tesla generator is applied to the classic ship gap between 5.0-30.0 cm. the minimum inception voltage that can create corona phenomenon or early streamer at the operating voltage of 10.0-33.85 kV. This operating voltage is lower than the HVDC and HVAC as the Tesla generator can generate high voltage and frequency. The field utilizations are close to the same value due to the same gap of the classic applied with difference source. The spark over voltages in the straight line, separate line of 5-9 lines, and separate line of 5-7 lines and strong corona or early streamer in middle and another pole are shown in Fig. 11, 12 and 13, respectively.

Conclusions

From this St. Elmo's fire corona phenomenon principle lead to research on the early streamer air terminal device to protect the tall building from being lightning strike. The HVDC and HVAC can generate St. Elmo's fire corona phenomenon only flash over or breakdown voltage point. Based on the experiment on high electric field early streamer apparatus, the streamer generator must be generated at the frequency range higher than 50 kHz with high voltage utilization factor less than 0.78.

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